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MARCH 1962



# PRINTER, PROJECTION, PHOTOGRAPHIC, EN-49

LOUIS D. TANGORRA
GEORGE NERSHI

FARRAND OPTICAL CO., INC.
4401 BRONX BOULEVARD
NEW YORK 70, N.Y.

TECHNICAL REPORT
E.R. 426R

CONTRACT NO. AF 30(602)2208

PREPARED FOR:

ROME AIR DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

GRIFFISS AIR FORCE BASE
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## ABSTRACT

The purpose of this report is to bring to the attention of the user a diapositive printer versatile and capable in operation to perform the functions of several pieces of printing equipment in current use. The report explains the versatility and capabilities of the printer and functional aspects of each design feature from the time of its inception to the final stage of completion, including the engineering problems encountered and steps taken to correct these deficiencies.

Today in the field of photogrammetry the present methods of diapositive printing require a separate printer for each film size and focal length used. To eliminate this multiple requirement, the idea of combining the functional requirements of several printers into one versatile piece of equipment was conceived. Farrand Optical Co., Inc. of Bronx, New York was awarded this task under contract AF 30(602)2208 from R.A.D.C., Rome, New York.

By application of engineering principles and design techniques, it was possible to design and fabricate subject diapositive printer EN-49 to accomplish all the required functions of several printers into one.

The versatility and capabilities of this new printer can be fully appreciated when taking into account the various functions it performs.

The printer accommodates three sizes of film format, 2 1/4" x 2 1/4" (70 mm film), 4.5" x 4.5" and 9.0" x 9.0".

By a system of projection lenses it can produce either exact geometry or constant size diapositive prints from any of the specified formats. The diapositive prints are subsequently mounted, stereoscopically viewed and evaluated by use of a Balplex plotter or similar equipment.

A unique feature is the simple and foolproof method to align the principal point of the film format to the projection axis. Heretofore fiducial marks were separately aligned with an individual magnification system for each fiducial mark. This method is now entirely eliminated by simultaneously projecting the four fiducial marks onto a viewing screen mounted in front of the operator. By operating the control knobs the operator can easily define and position the marks to the crossline reticle inscribed on the viewing screen.

# LIST OF ILLUSTRATIONS

# INTRODUCTION

The main requirement of this contract is to design a diapositive printer that has a capability of producing diapositives on 110 mm square plates using several combinations of film formats and camera focal lengths.

These combinations are as follows:

| Format Size | Focal Length of Camera Lenses | | |
|---|---|---|---|
| 70 mm | 1 1/2" | 3" | 6" |
| 4 1/2" x 4 1/2" | 3" | 6" | 12" |
| 9" x 9" | 6" | 12" | 18" |

The diapositives are to be suitable for projection in stereoplotters whose principal distances are 55 mm.

The camera lenses specified necessitate various projection ratios between the film and diapositive. This is done in a nominally constant film to dispoaitive distance. The focal lengths of all projection lenses are such as to produce the necessary magnification in approximately the same conjugate distance. The diapositive plane is variable in position. This makes it possible to make a "zero" setting of the diapositive plane for each of the four projection systems. Additional axial adjustments are provided, by means of micrometer dials, to vary the projection lens and diapositive positions as required by the calibrated focal length of the camera lens.

## DISCUSSION

Design study at the beginning of this project centered around the choice of lenses to project the film to the diapositive. In order to reproduce the geometry of the photographs when projected in a stereoplotter, which has a projector principal distance of 55 mm, the lenses must magnify the photographic negative by the ratio of 55 mm to the calibrated focal length of the camera lens.

For the stereoplotter to form an exact spatial scale model of the photographed area, the diapositive must be magnified (or reduced) from the original negative by the ratio of the principal distance of the projection to the calibrated focal length of the camera lens as follows:

$$M = \frac{p}{f}$$

where p = 55 mm and the nominal values of f are 1.5", 3", 6", 12" and 18".

Values for M for these lenses are 1.4436, .72178, .36089, .18045 and .12030.

When diapositives from successive negatives are printed to these magnifications (or reductions) they can be used in projection plotters to produce a theoretically perfect scale model of the terrain.

These magnifications when applied to the film formats and camera lenses specified would result in the following size diapositives:

| Format | Lens | Diapositive Size |
|---|---|---|
| 70 mm film | 1.5" | 3.248" sq. |
| 4.5 x 4.5 | 3" | 3.248 |
| 9 x 9 | 6" | 3.248 |
| 70 mm film | 3" | 1.624" sq. |
| 4.5 x 4.5 | 6" | 1.624 |
| 9 x 9 | 12" | 1.624 |
| 70 mm film | 6" | .806 |
| 4.5 x 4.5 | 12" | .806 |
| 9 x 9 | 18" | 1.083" |

It is apparent that the narrow field photography would result in diapositives that are too small to be advantageously used.

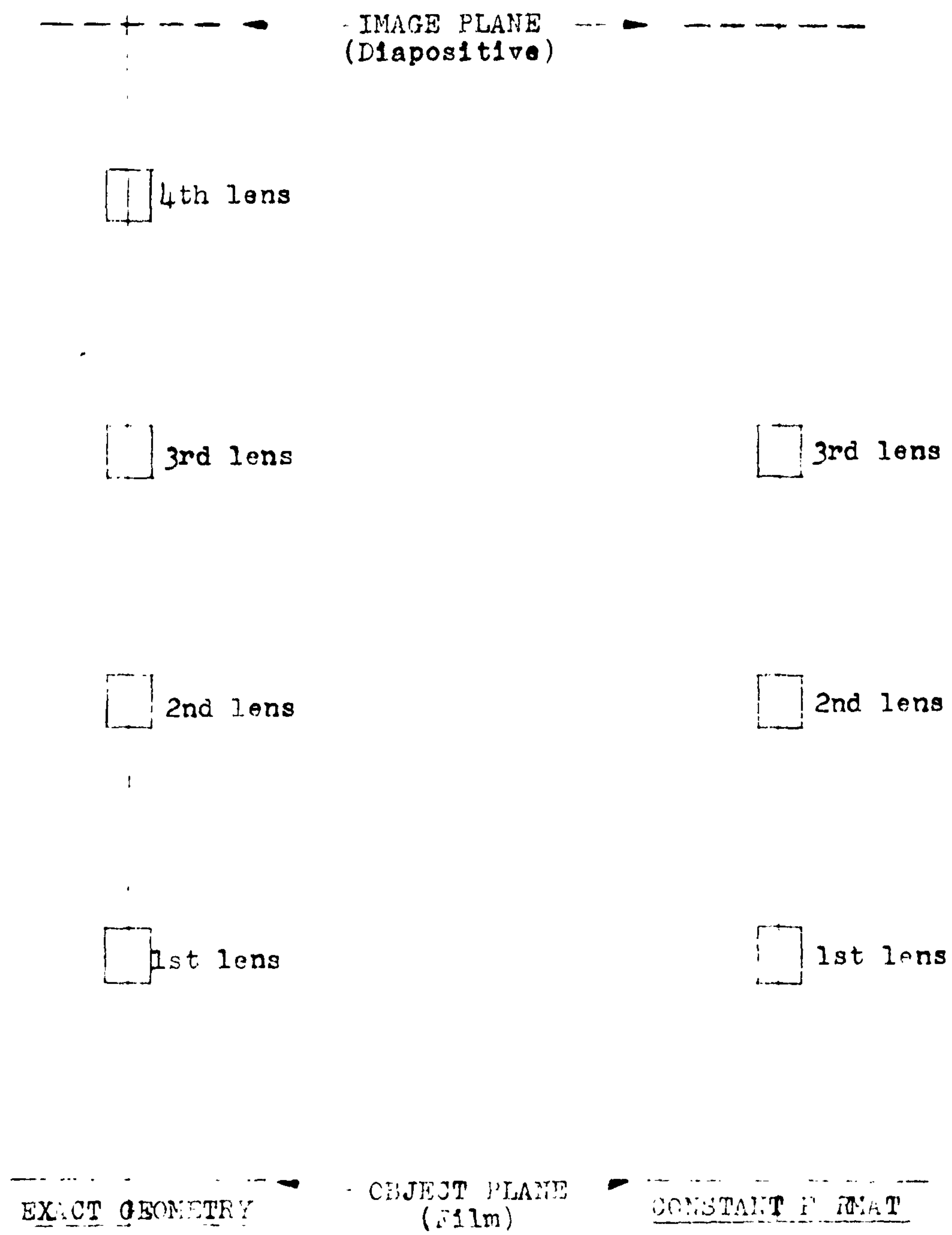
Moreover, since the distance between the principal points of successive diapositives, as mounted in the projectors, must represent the air base to the map scale, it is physically impossible to set up this distance between the projectors. For this reason, the requirement for printing the narrow field photography to result in a true geometrical model was eliminated. This, therefore, eliminated the need for a magnification of .12030.

The remaining four magnifications are sufficient to provide either or both "exact geometry" or "constant format" diapositive printing for all types of photography specified.

The four magnifications are accomplished in a nominally constant overall projection distance (approximately 820 mm) between the film and diapositive planes. This is made possible by the choice of focal lengths of projection lenses that were selected for their recognized photogrammetric qualities. Additional optical components in the main projector consist of a glass pressure plate and a correction plate between which the film is supported. Also a compensating plate is mounted on the diapositive side of each lens. This is the optical equivalent of the correction plate and is used to correct the distortion. The lenses which will be referred to as Lens Nos. 1, 2, 3 and 4 are set up as follows:

| Lens No. | Lens Focal Length | Film Distance / Diapositive Distance |
|---|---|---|
| 1 | 200 mm | 1:1.4436 |
| 2 | 200 mm | 1:1.72178 |
| 3 | 160 mm | 1:.36089 |
| 4 | 105 mm | 1:.18045 |

The magnifications listed in the last column are nominal. Variations from these nominal values are needed because of variations in calibrated focal lengths and film shrinkage or expansion. To perform these adjustments, micrometer type collars provided on each lens and on the diapositive holder allow for changing the position of the lens and the diapositive. Charts are provided to indicate the correct settings of the micrometers as a function of the calibrated focal lengths. This procedure will result in "exact geometry" diapositives. Figure 1 shows that "exact geometry" diapositives can be made by using lens Nos. 1, 2, 3 and 4 for photography from 1 1/2, 3, 6 and 9 inch focal length lenses respectively regardless of film format size. Figure 1 also shows that




| Camera F.L. | Format Size | Lens No. |
|---|---|---|
| $1\frac{1}{2}$ | any | 1 |
| 3 | | 2 |
| 6 | | 3 |
| 9 | ″ | 4 |

| Format Size | Camera F.L. | Lens No. |
|---|---|---|
| 70 mm | any | 1 |
| $4\frac{1}{2} \times 4\frac{1}{2}$ | | 2 |
| $9 \times 9$ | ″ | 3 |

Figure 1. **Exact Geometry and Constant Format Schematic**

"constant format" (3.248 inches square) can be made by using Lens Nos. 1, 2 and 3 with 70 mm, 4 1/2" x 4 1/2" and 9" x 9" formats respectively regardless of camera focal length. The user of the printer then has the option of making constant format diapositives from all types of photography or exact geometry diapositives from all types except narrow field photography.

It must be remembered that V-H exaggeration will occur in the constant format mode. The following table provides information for constant format narrow field photography and also for constant format medium field photography.

CONSTANT FORMAT (NARROW FIELD)

| Film | Camera F.L. | Make Settings for | Use Lens No. | Diapositive PD |
|---|---|---|---|---|
| 70 mm | 6" | 1/4 CFL | 1 | 13.5 mm |
| 4 1/2 x 4 1/2 | 12" | 1/4 CFL | 2 | 13.5 mm |
| 9 x 9 | 18" | 1/3 CFL | 3 | 18.33 mm |

CONSTANT FORMAT (MEDIUM FIELD)

| Film | Camera F.L. | Make Settings for | Use Lens No. | Diapositive PD |
|---|---|---|---|---|
| 70 mm | 3" | 1/2 CFL | 1 | 27.5 mm |
| 4 1/2 x 4 1/2 | 6" | 1/2 CFL | 2 | 27.5 mm |
| 9 x 9 | 12" | 1/2 CFL | 3 | 27.5 mm |

Having established the optical parameters the following design requirements became obvious.

a) A yoke and housing to support the cathode tube with a device to easily remove the tube for repair or replacement.

b) Fiducial mark projection systems.

c) A light source mechanism or attachment to illuminate and project the fiducial marks on a viewing screen.

d) Controls to transport the film format in forward and azimuth motion for aligning the projected fiducial marks.

e) A device to securely clamp the film during the printing operation.

f) A lens mounting plate assembly for each of the four projection lenses with a means to easily select, insert and remove the lens for the required projection, including a locking and stowing device for each assembly, the locking device to insure repeatability of positioning the lens in the optical path.

g) Fine and coarse micrometer settings for each lens barrel within .0005 inch.

h) A focussable diapositive plate mount with fine and coarse micrometer settings within .0005 inch.

i) A hinged photo-tube housing to permit easy insertion and removal of the diapositive plate.

j) An indexing device to mount the fiducial marks projecting systems, permitting repeatability of alignment to the cross-line on the viewing screen.

k) Spool rods to accommodate the three different size film spools.

l) An automatic electronic dodging device to produce diapositive prints of uniform density.

Tabulation of the above requirements indicated that repeatability and stability of the equipment was of major importance to consistently produce accurate diapositive prints. Accuracy in positioning the projection lenses, format focal plane and diapositive focal plane was also obviously apparent.

With clarification of the requirements a preliminary overall design was initiated. Foremost in thought was the selection of the proper materials to satisfy the requirements. Rigidity and structural strength analysis computations were carried out of the characteristics of various materials to insure maximum stability of the structural members. Of the various materials considered (aluminum, steel weldment, Meehanite, titanium) the outstanding characteristics of Meehanite Type GA indicated that this material was most favorable to the application: but with the disadvantage of weight and cost factors.

The use of Titanium would incur prohibitive material cost and special machining techniques. A steel weldment structure would be satisfactory except that the final product would not appeal to the eye.

Compiling this information of the various materials and weighing all the factors it was decided that with proper ribbing and structure configuration Alum alloy 195-T6 was the proper material to be used because of its low cost, ease of machining and low weight factor. Discussions with the foundry engineers attested to the decision of using this material. With collaboration between design and foundry personnel the main structural members were designed and cast for the maximum properties of rigidity and stability.

With the approximate configuration of the main structural members established and conceived it was possible to design the various design features into the system, keeping in mind that simplicity of the component parts would insure the greatest degree of maintainability.

With this concept, all sliding and bearing surfaces were designed with materials inherent with properties favorable to abrasive action. All surfaces are protected with standard accepted anodic coatings or paint. All rust inhibited materials were eliminated, thereby insuring the equipment for a long trouble free, operational life.

The preliminary design was advanced to the point where it was possible to discuss with R.A.D.C. the salient points in the design and its operation. By discussion and analysis it was possible to arrive at conclusions and eliminations of design points not necessary or required in the final design. This intermediate step paved the way to a final design embracing all the requirements of the specifications without unnecessary embellishments.

In its present form the diapositive printer EN-49 (Figure 2) stands 5 feet 11 inches high and is 31 inches wide. It is comprised of three major assemblies - Base Assembly (Figure 3), Lower Case Assembly (Figure 4) and Upper Case Assembly (Figure 5).

The Base Assembly (Figure 3) is fitted with four large-diameter casters to provide ease of mobility. These casters can be locked to provide a stable platform. The housing is of weldment construction and has a removable rear panel. The assembly houses a 17-inch cathode tube which is mounted in a tilt table cradle to permit removal and repair. The tube is part of the electronic illuminating and dodging system used to expose the diapositives.

The Lower Case Assembly (Figure 4) houses the format transport mechanism (Figure 6) a mirror and screen which are part of the fiducial mark projection systems, and the film spool supporting arms. The format transport mechanism accommodates any one of three mask assemblies used for the specific film size (Figure 7). Each mask assembly serves a dual purpose; first, it provides a margin of 1/2-inch around the film format. In this half-inch margin the average density of the film is extended to the edge of the mask by means of a frame of film. This is necessary for proper operation of the electronic dodging system. Second, each mask assembly carries four fiducial mark projectors. By means of a pivot point, a slotted "V" groove and free bearing point, each mask assembly can be indexed and accurately repositioned in reference to the optical axis.

The mask assemblies simultaneously present images of the four fiducial marks magnified 8X to the screen in front of the

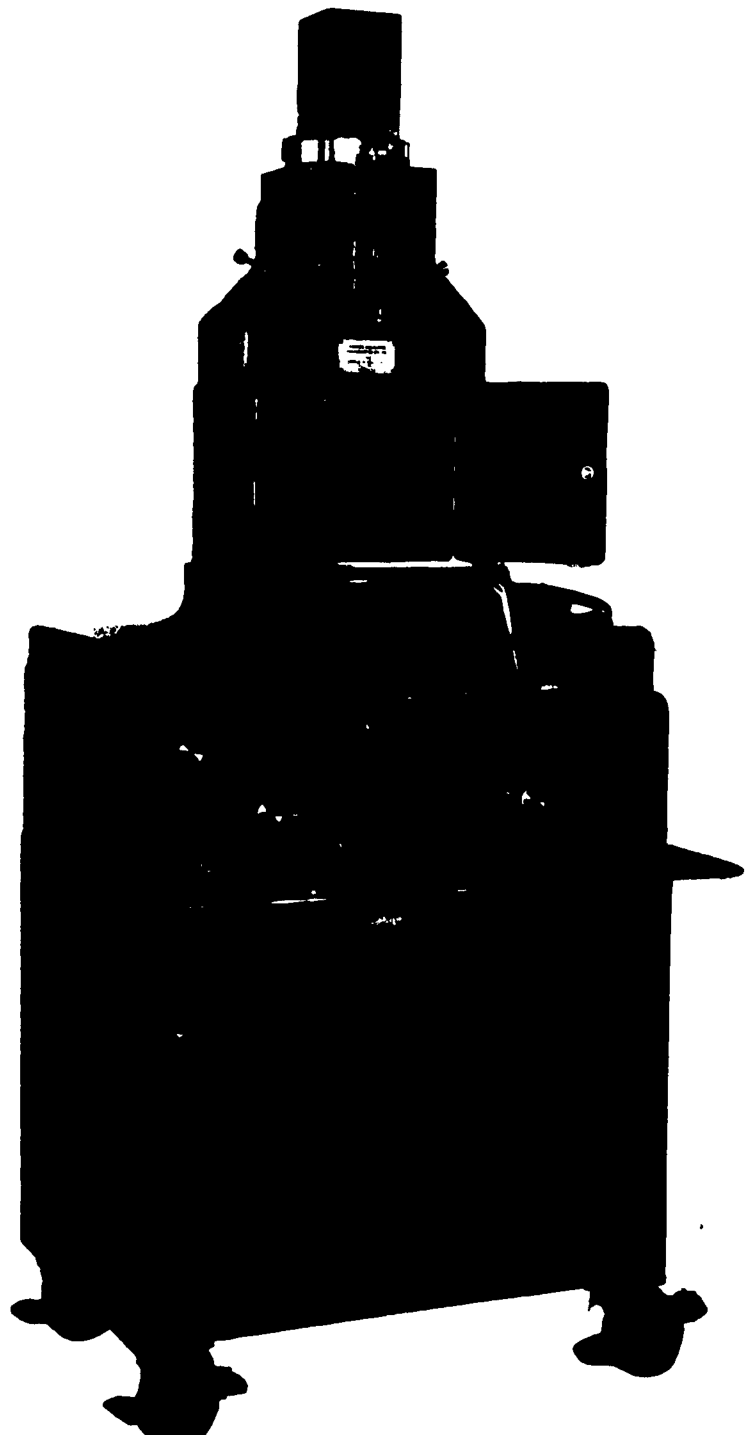


FIGURE 2. DIAPOSITIVE PRINTER EN-49

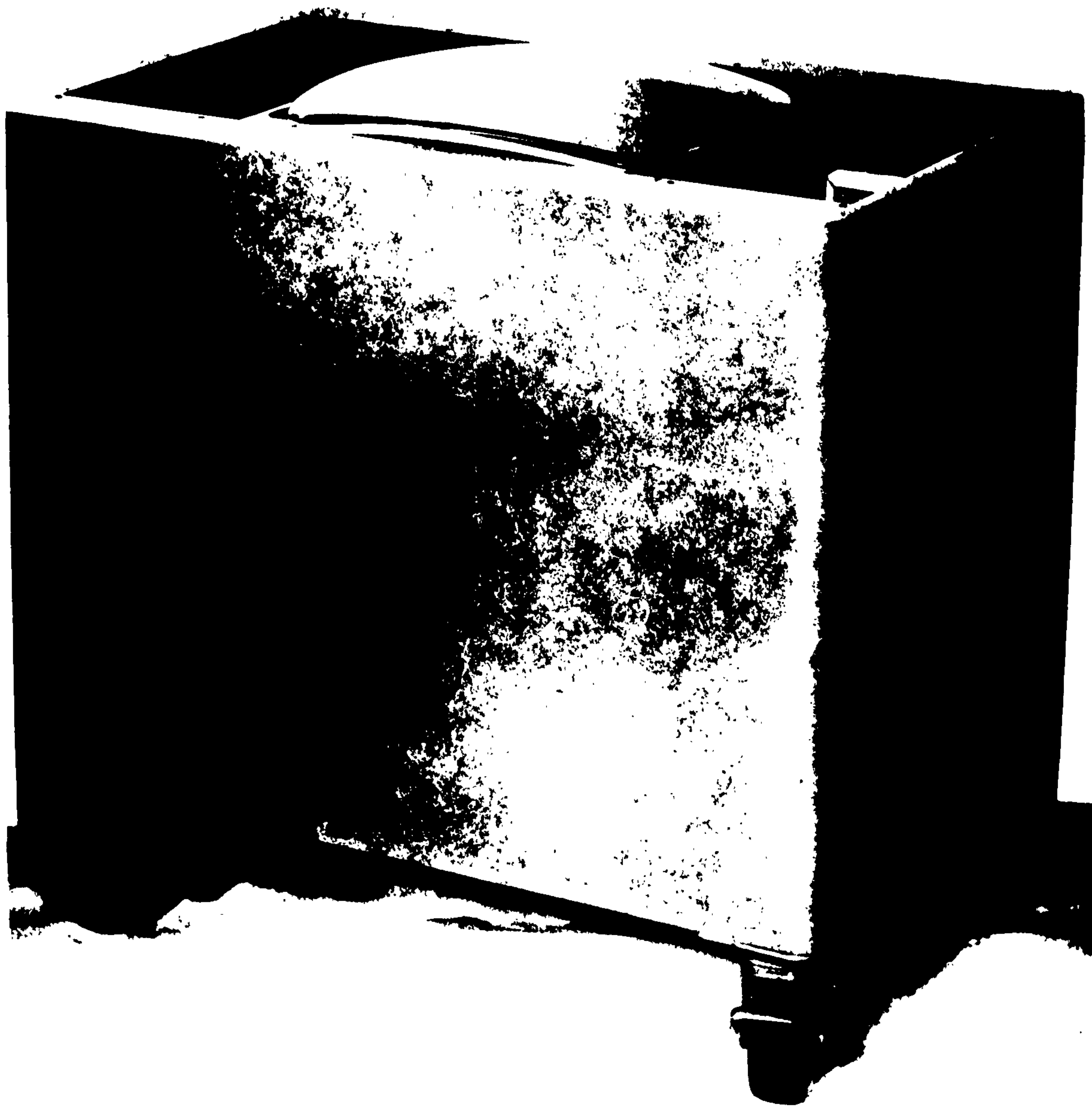


FIGURE 3. BASE ASSEMBLY

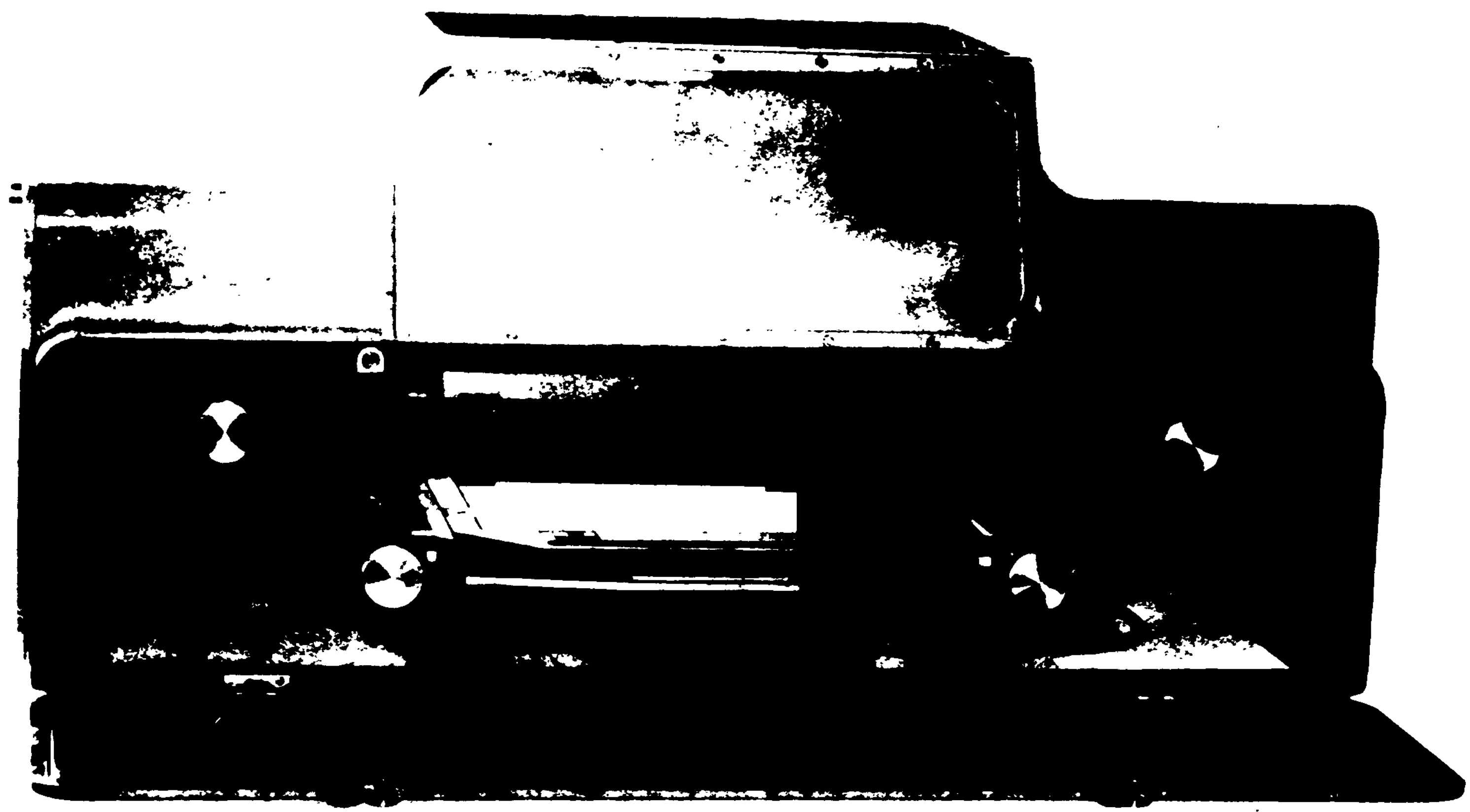


FIGURE 4. LOWER CASE ASSEMBLY

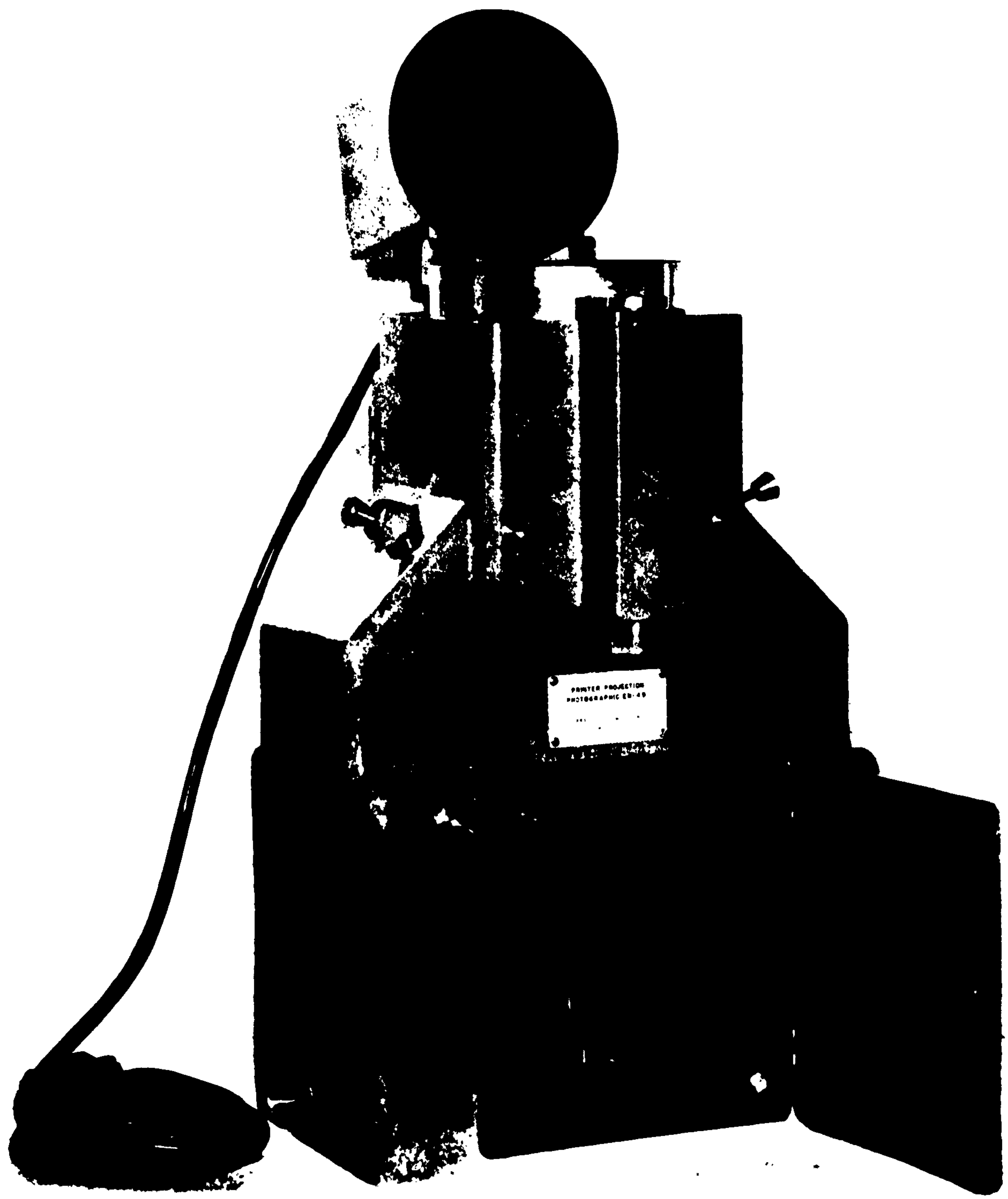



FIGURE 5. UPPER CASE ASSEMBLY

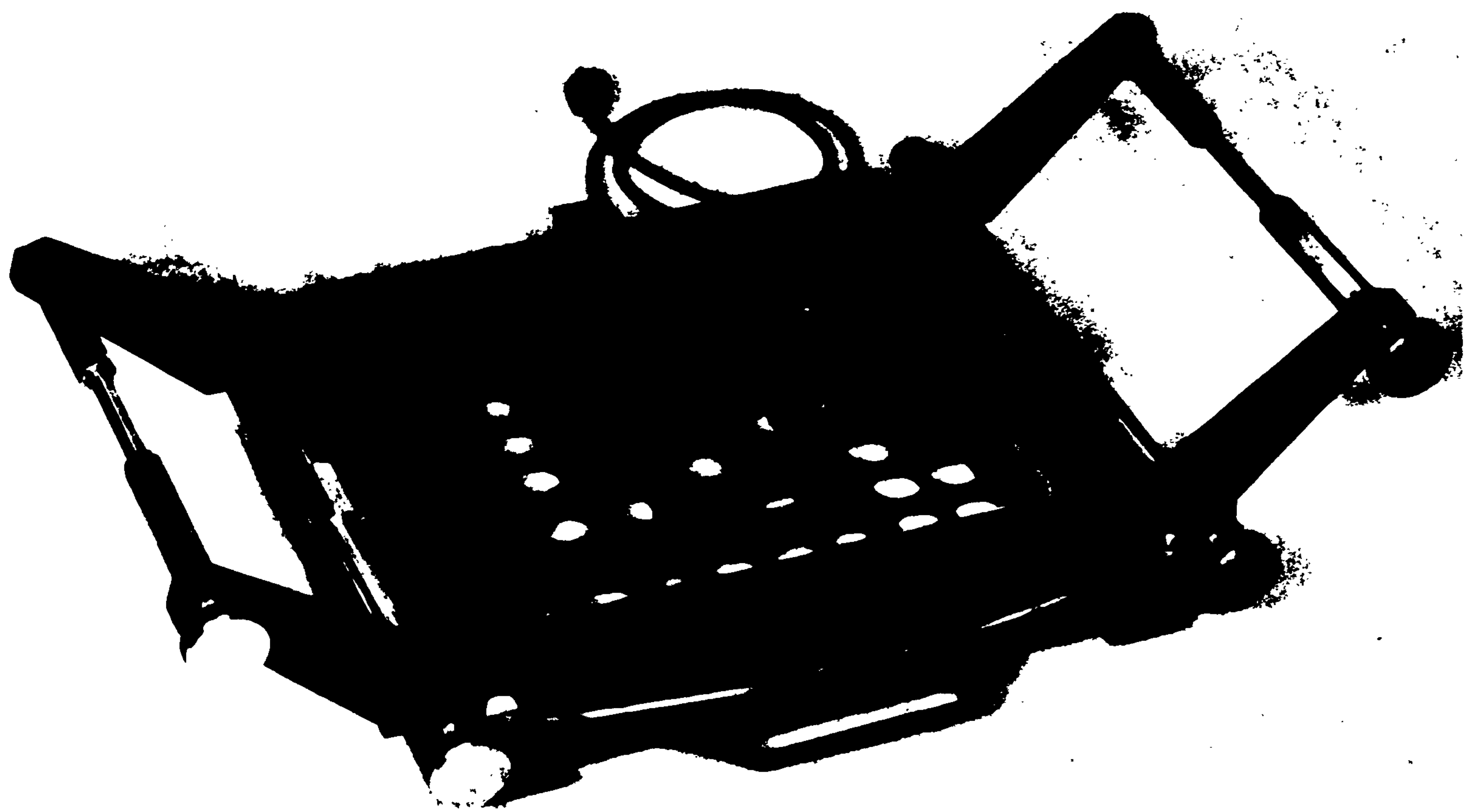


FIGURE 6. FORMAT TRANSPORT MECHANISM

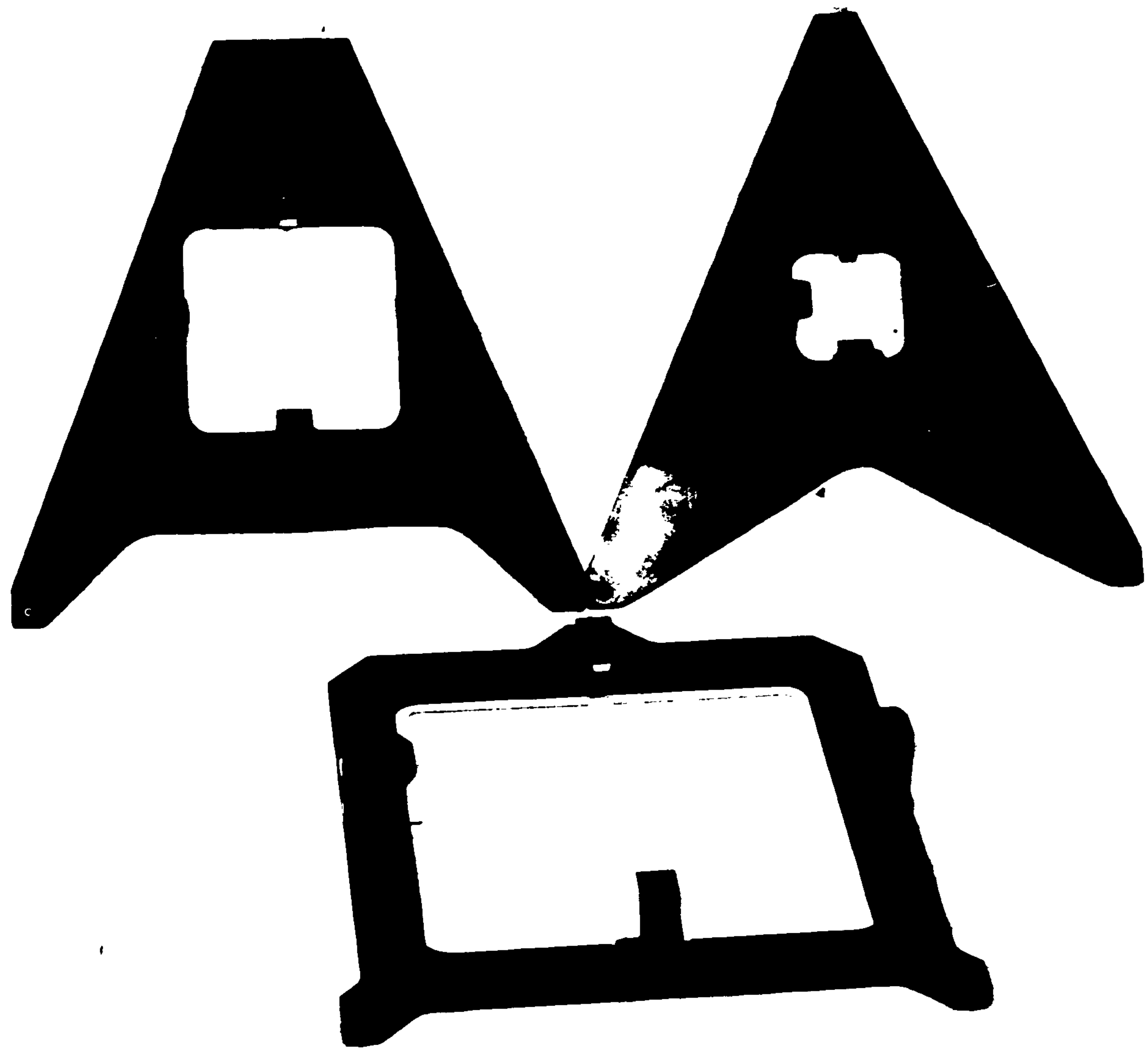


FIGURE 7. MASK ASSEMBLIES

operator (Figure 8). By utilizing the film control motions provided in the format transport mechanism, the fiducial marks are visually and readily aligned to the screen reticle. When alignment has been obtained, the principal point of the film coincides with the principal point of the film projection lens. To project the images, a light tray assembly (Figure 9) is inserted into the format transport assembly to provide illumination for the fiducial mark projectors. Electrical contact is automatic when the tray is inserted by engagement of the electrical connector. Three switches located at the front of the light tray select the proper array of projection lights required for the specific size film being projected. This must be removed before actual printing commences.

The format transport assembly also contains the glass correction plate assembly, pressure plate assembly, pressure slide, traverse frame and azimuth plate.

Mounted to the traverse frame are the film spool supporting arms which straddle and engage the film spools by means of a spring loaded key and fixed bearing point.

The lower surface of the glass correction plate defines the film focal plane. The pressure plate by means of the pressure slide securely clamps and holds the film during alignment and projection.

Light-sealing covers on both sides and front permit removal of film spools and accessibility to control knobs.

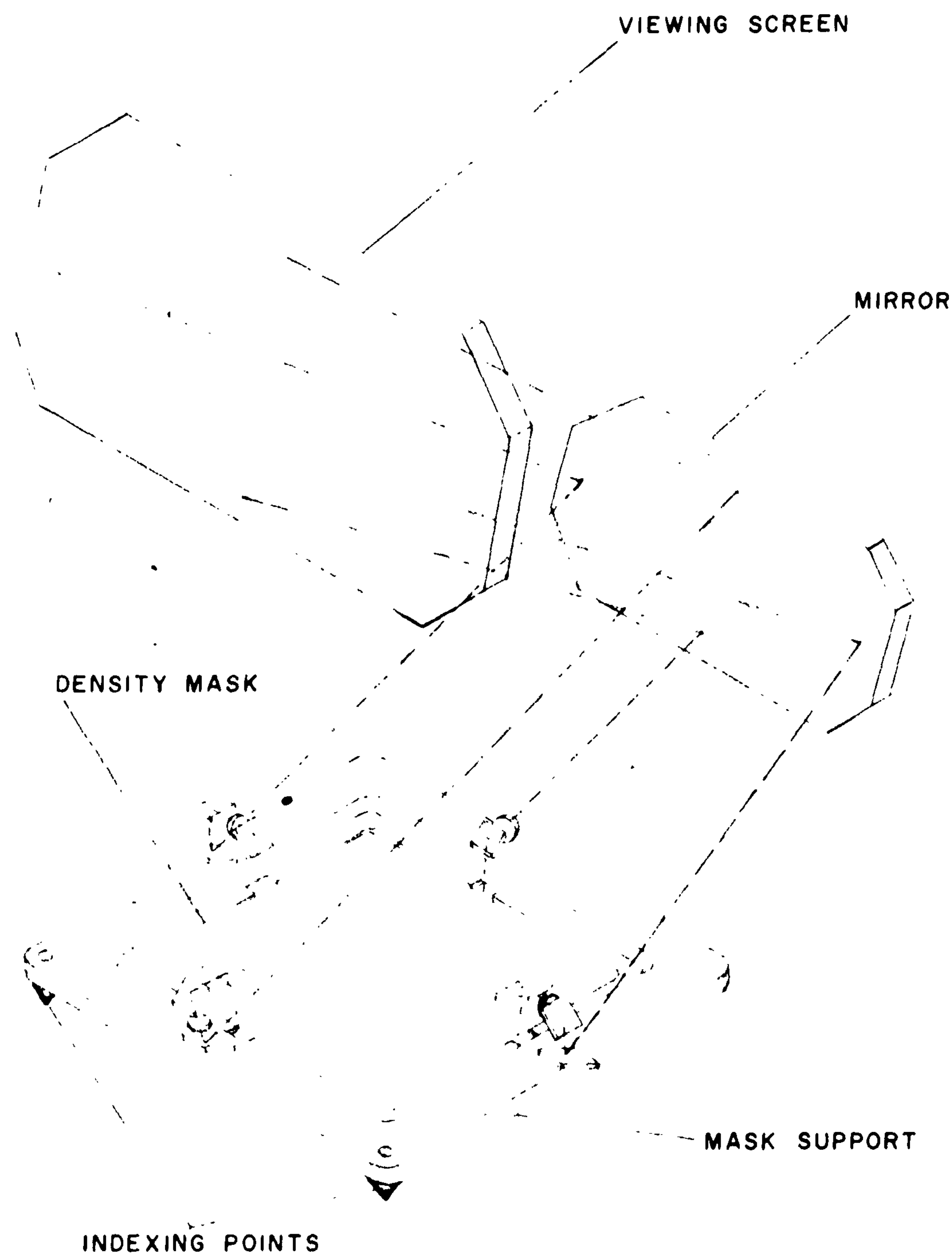



FIGURE 8. TYPICAL FIDUCIAL MARK PROJECTION SYSTEM

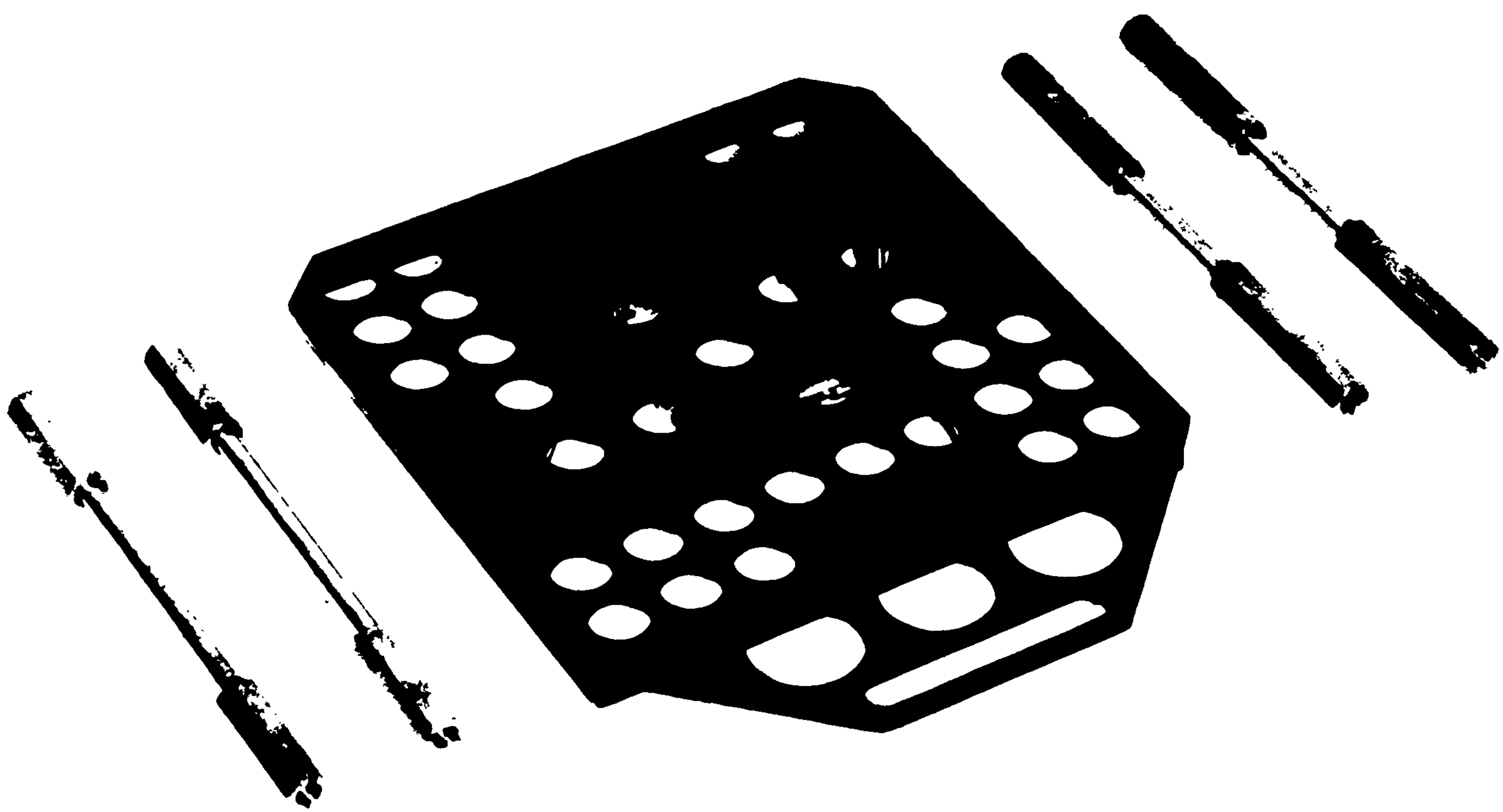


FIGURE 9. LIGHT TRAY ASSEMBLY

The light tray assembly, three mask assemblies and spool adapter rods are provided as accessory items stowed when not in use in Case (Figure 10).

The Upper Case Assembly (Figure 5) contains the photo-multiplier tube and housing assembly, the focussing cylinder mounting the diapositive plate and four projection lenses mounted on individual pivoting plates. The plate and lens assemblies swing out of position when not being used and are stowed by the stow pin assemblies.

The photomultiplier tube senses the degree of light emitted through the diapositive plate (without anti-halation backing) and the signal triggers the rate of scan of the light beam. Therefore dense areas of the negative will linearly slow down the rate of scan and vice versa.

The photomultiplier tube can be removed from the hinged housing assembly by unscrewing the gland nut holding the assembly in place. The housing is hinged to the focussing cylinder for removal and insertion of the diapositive plates. When the housing is closed foam rubber pads press against the plate to firmly hold it in position without strain.

The focussing cylinder is supported by a lead screw drive and contains all the supporting points for the diapositive plate which consist of four mounting pads and two spring clips positioning the plate in the horizontal plane. At final assembly the four pads are accurately ground flat and parallel to the film format plane by auto-collimation.

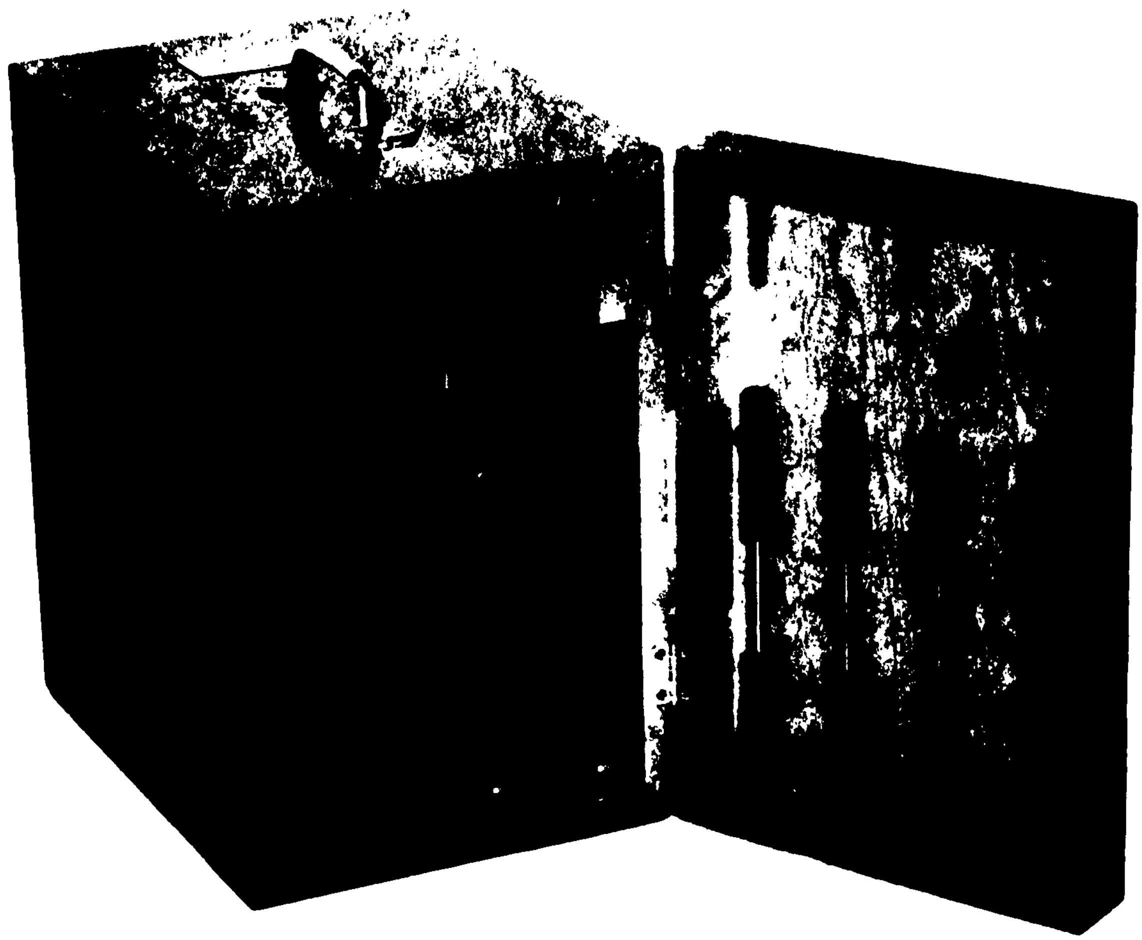


FIGURE 10. ACCESSORY CASE

The cylinder is made of stainless steel and attached to a bronze bearing support which receives the stainless steel lead screw. At assembly the lead screw and members are lapped to insure precise vertical adjustment of the diapositive focal plane. By selection of the materials trouble free and long operation life is assured.

A coarse reading on the cylinder barrel and fine reading micrometer dialscoupled to the lead screw accurately positions the diapositive focal plane to pre-determined settings.

Each projection lens (Figure 11) is mounted onto a hinged plate which can be pivoted out of the optical path and stowed when not being used. When in use the plate and projection lens assembly is pivoted and held in place against its reference surface by a tapered lock-pin assembly which consists of a spring loaded taper shaft constantly exerting pressure to maintain the lens plate assembly against the reference surface.

The projection lens assemblies consist of the lens assembly, inner and outer micrometer barrel and leveling plate. The lens assembly is mounted in the inner micrometer barrel and secured with a retaining ring. The screw thread and outside diameter of the barrel are then machined on an auto-collimating lathe co-axial to the lens optical axis, thereby assuring that the lens axis is maintained co-linear with the optical axis of the printer at various settings of the lens. The outer and inner barrel indicates the fine and

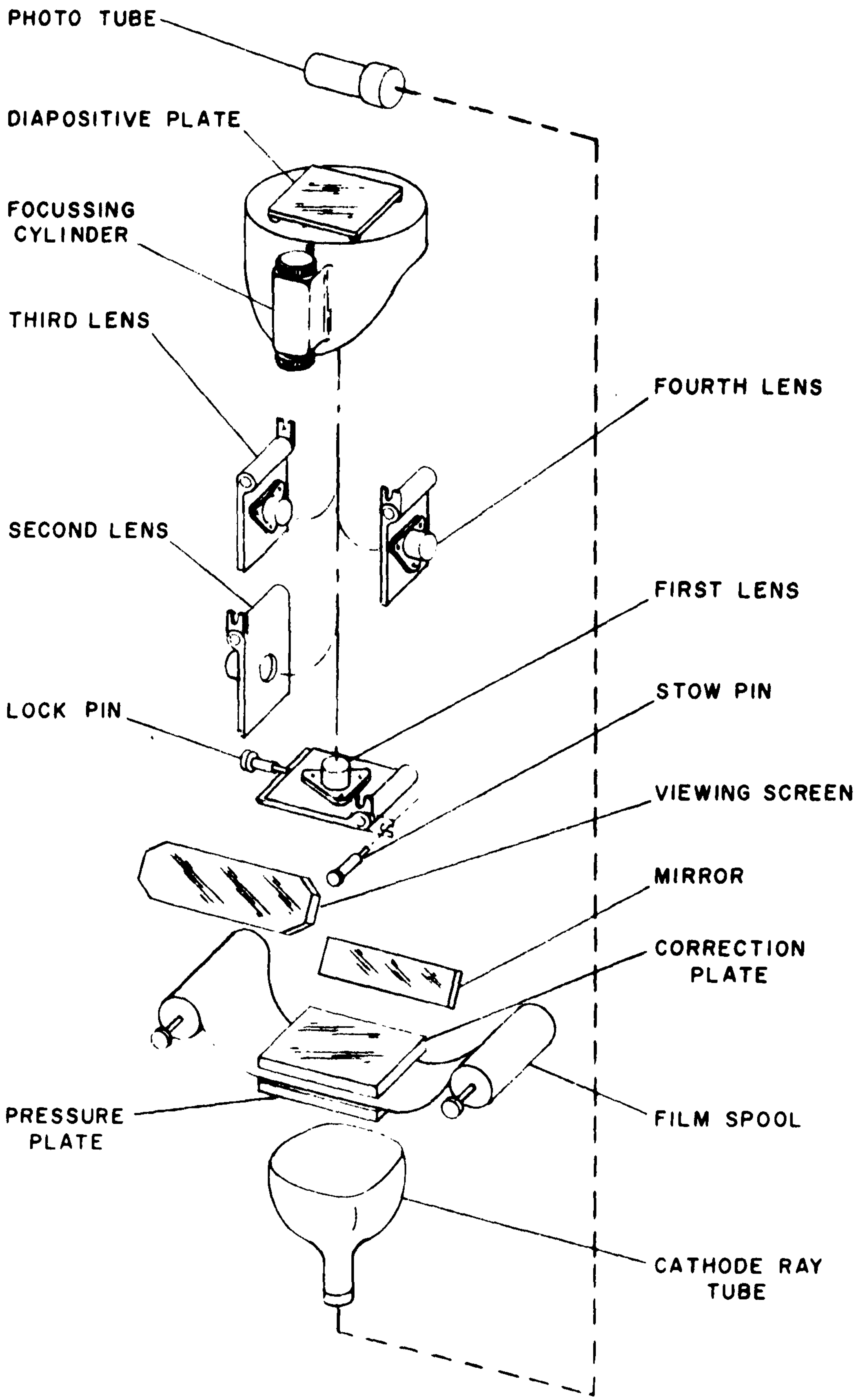



FIGURE 11. SCHEMATIC DIAPOSITIVE PRINTER

coarse micrometer readings, which accurately position the lens to the prescribed settings for either exact geometry or exact image pointing. The complete lens assembly is adjusted in the horizontal plane and tilted by means of the adjusting screws to align the projection axis to the main optical axis. Accessability to the lens assemblies is by means of the light sealing covers.

The pre-determined settings of the projection lenses and focussing cylinder are established by precise calibration of the true focal lengths of the lenses. This is necessary to insure maximum accuracy and quality in the diapositive print. Replacement of the projection lens would require alignment and re-calibration of the system for that particular lens.

A "Log-E-tron" console-model VM90 (Figure 12) provides the completely automatic dodging feature incorporated in the system. By means of the photomultiplier tube and feedback loop the velocity of the "flying spot" light source is varied according to the varying densities of the film to produce prints of uniform density.

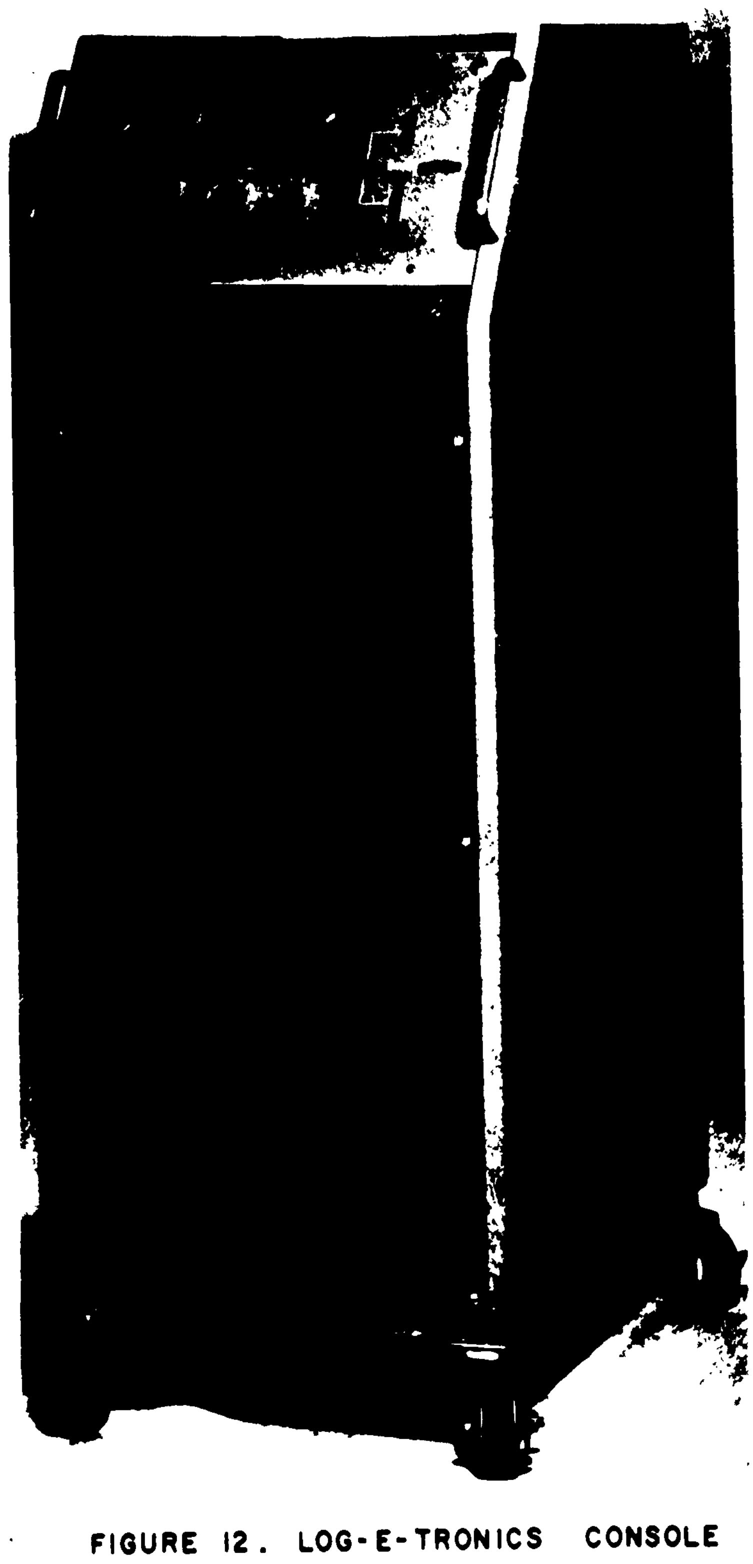


FIGURE 12. LOG-E-TRONICS CONSOLE